

DIRECTORY

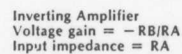
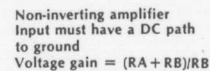
This directory has two functions: firstly, as a source of complete circuits that can be used without modification, where you may find exactly the circuit you need. Secondly, and of much wider application, the directory will provide ideas that can form the basis of your own, custom-designed circuits.

Maximum frequency = 10 kHz
Linearity = 0.05%
Response time = 10 μ s
Op-amp powered from ± 15 V

Output frequency $F = (\text{pot fraction})/2RC$
 Pot fraction can be 1/1 to 1/100, giving a 100 to 1 range from the pot
 Suitable frequency range = 0.01 Hz to 50 kHz
 Run op-amps from ± 12 V

Using an external transistor to reduce the input voltage and power dissipation to a safe level.

Voltage follower/buffer
Input must have a DC path to ground



Voltage gain (fixed) = $\times 50$ (34 dB)
 $+V_{CC}$ range = +8 V to +22 V
 Typical quiescent current = 7 mA
 Output power = 2W5 (with speaker = 8R, heatsink fitted)

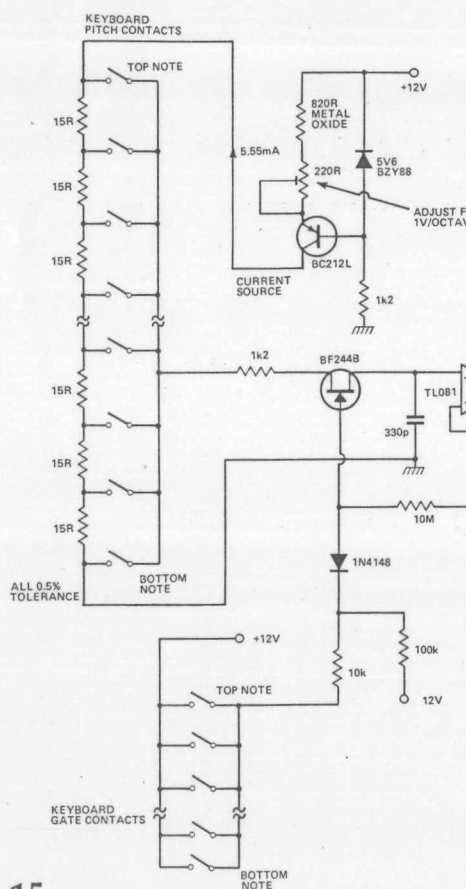


For low frequencies use TL081 op-amps
Frequency range 0.1 Hz to 10 kHz



Input is a sinewave or any other periodic waveform, maximum level ± 2 V, maximum frequency 100 kHz
Output is a tone burst variable from one cycle on, 15 cycles off to 15 cycles on, one cycle off
All devices powered from ± 6 V

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BCD-to-seven-segment
Latch/Decoder/Driver for LCD Display

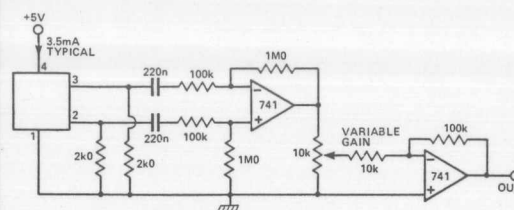
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Keyboard Unit

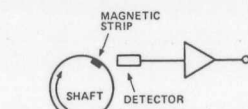
Adjust the keyboard contacts so that the pitch contacts make before the gate contacts

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Magnetic Field Detector

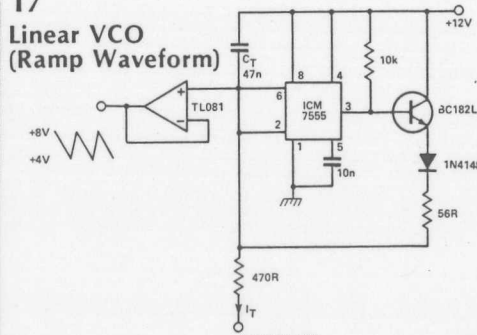


Circuit is AC-coupled
The linear Hall effect IC is the 6345S2 (RS 304 267)
Maximum gain = +40 dB
Detector sensitivity = 7.5 mV to 10.6 mV/mT
Detector frequency response = DC to 100 kHz



Circuit can be used as a tachometer

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Linear VCO
(Ramp Waveform)

Output frequency $F = I_T / 4 C_T$
If $I_T = 1\text{mA}$, $C_T = 47\text{n}$, then $F = 5.3\text{ kHz}$

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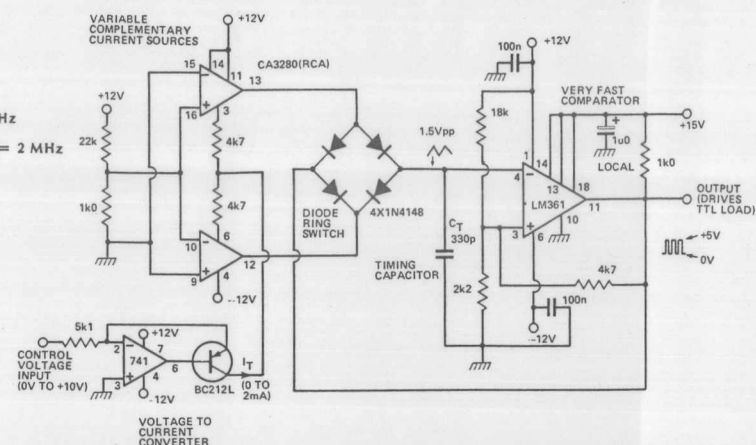
Fast VCO

Oscillation frequency $F = I_T / 3 C_T \text{ Hz}$

If $I_T = 2\text{ mA}$, $C_T = 330\text{p}$, then $F = 2\text{ MHz}$

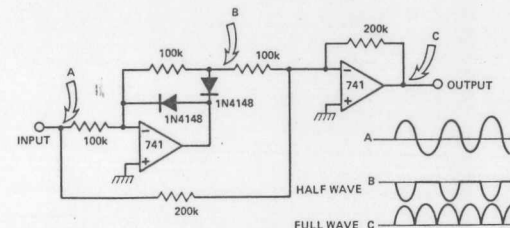
Alter C_T to increase F

Maximum frequency = 10 MHz



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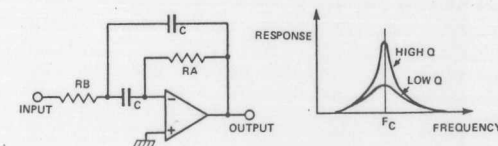
Precision Full Wave Rectifier



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Band Pass Active Filter

$F_C = 1/2 \pi C \sqrt{R_A + R_B}$
 $Q = 1/2 \sqrt{R_A/R_B}$
Gain = $2Q^2$



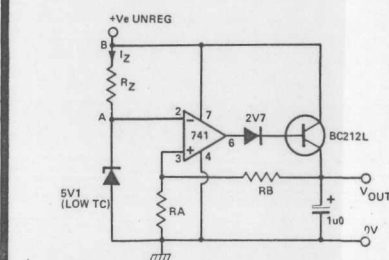
$F_C = 1\text{ kHz}$, $C = 15\text{ n}$

RA	RB	Q	GAIN
10k6	10k6	0.5	x 0.5
21k2	5k3	1.0	x 2.0
42k4	2k65	2.0	x 8.0
84k8	1k32	4.0	x 32.0

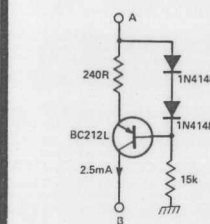
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Battery Regulator



A very low dropout voltage can be obtained by allowing Q1 to saturate. This gives maximum lifetime on battery power.



Better regulation can be obtained by replacing RZ with this 2.5 mA current source. However, the unregulated supply rail must not drop below $(5V1 + 1V2) = 6V3$

Select R_Z for an I_Z of about 2.5 mA

$V_{OUT} = 5V1 \times (R_A + R_B)/R_A$

Minimum $V_{OUT} \sim 6V$

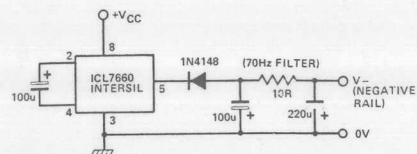
Dropout voltage = $V_{CE}(Q1 \text{ saturated}) \sim 0V3$

Keep I_{OUT} less than 50 mA

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Generating Negative Supply Rails

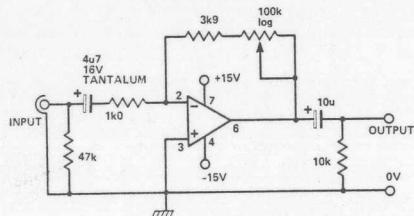


$V^- = (+V_{CC} - 0V7)$
 Typical efficiency = 98%
 Quiescent current = 170 μ A
 $+V_{CC}$ range = 3 to 10 V
 Maximum output current = 40 mA
 Output resistance = 55 Ω

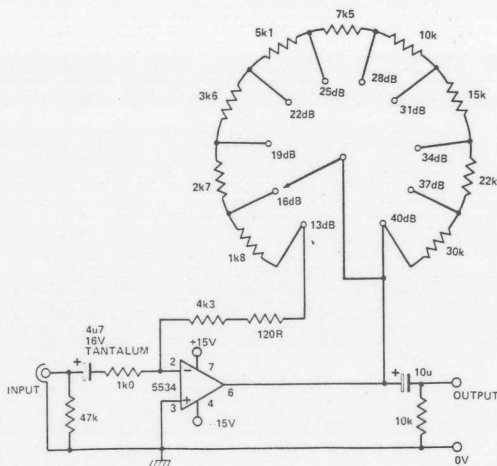
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Low Impedance Source Preamp

Very low input noise
 Input noise = 4 $nV/\sqrt{Hz}$
 Equivalent input noise voltage = 0.56 μV_{RMS} (20 kHz bandwidth)
 Input impedance = 1k Ω (suitable for microphone)



Variable gain; x 3.9 to x 100 (12 dB to 40 dB)

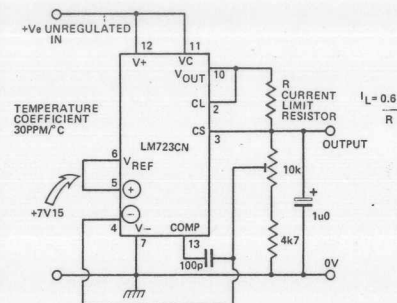


Switched gain; 3 dB steps

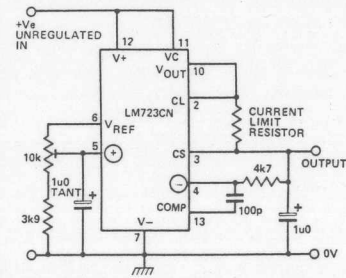
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Precision Power Supplies

723 general specifications:
 Maximum input voltage = 40 V
 Maximum input current = 150 mA
 Output voltage range = 2 to 37 V



Adjustable +7 V to +21 V

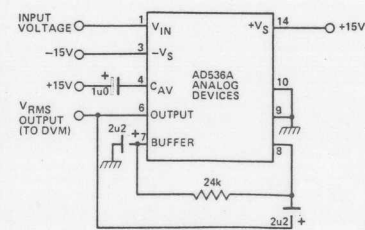


Adjustable +2 V to +7 V

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True RMS Measurement

Input voltage 7 V_{RMS} maximum
 Bandwidth: 300 kHz, $V_{RMS} > 0V1$
 Error of 1% for a crest factor of 7
 Quiescent current = 1mA
 60 dB range



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Unregulated Power Supplies

* Smoothing capacitor must have a voltage rating greater than the rail voltage.

TRANSFORMER
 SECONDARY
 VOLTAGE (V_{RMS})

4.5
 6.0
 9.0
 12.0
 15.0
 20.0

TYPICAL
 UNREGULATED
 DC VOLTAGE

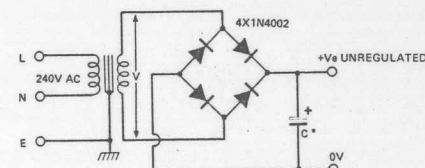
6.3
 8.4
 12.6
 16.8
 21.0
 28.0

APPROXIMATE RIPPLE VOLTAGES (V_{PP})

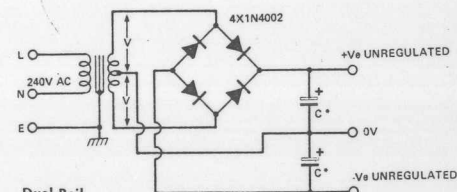
OUTPUT
 CURRENT

C = 470 μ C = 1000 μ C = 2200 μ

30 mA 0.42 0.21 0.10
 100 mA 1.4 0.7 0.32
 300 mA 4.2 2.1 0.96
 1 A 14.0 7.0 3.20



Single Rail



Dual Rail

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Parametric Equaliser

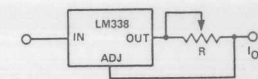


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Current Limiter

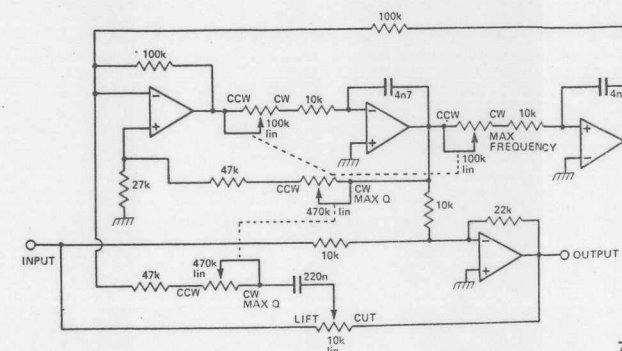
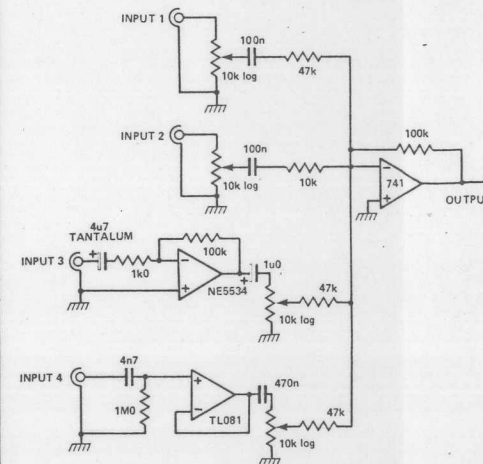
$0R4 < R < 120R$



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Simple Mixer

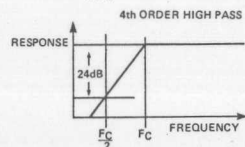
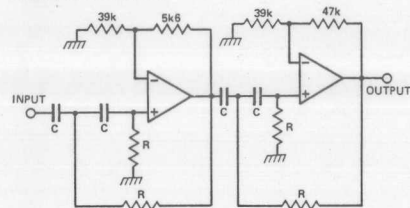
INPUT	MAX GAIN	INPUT IMPEDANCE	SOURCE
1	+6 dB	10k	line level
2	+20 dB	5 to 10k	line level
3	+46 dB	1k Ω	low impedance microphone input
4	+6 dB	1M Ω	high impedance input



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Rumble Filter



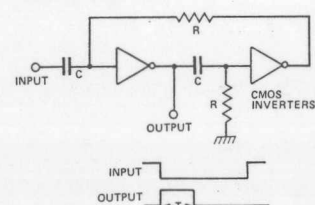
Roll-off slope = 24dB/octave
Overall voltage gain = $\times 2.6$ (8.3 dB)
Op-amps are 741's or RC4558

F_c	C	R
25 Hz	100n	62k
50 Hz	100n	30k
100 Hz	100n	15k
200 Hz	100n	7k5

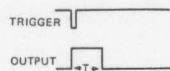
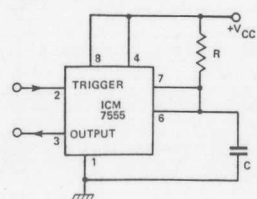
(5% tolerance)

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Monostables



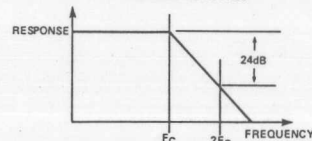
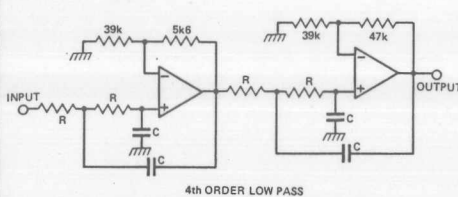
CMOS inverters
 $T = 1.38RC$
Keep R greater than 47k



CMOS 555
 $T = 1.1RC$

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Scratch Filter



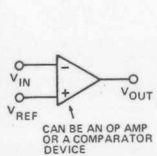
Input must have a DC path to ground
Roll-off slope = 24 dB/octave
Overall voltage gain = $\times 2.6$ (8.3 dB)
Op-amps are 741's or RC4558

F_c	C	R
10 kHz	1n5	10k
7.5 kHz	1n5	14k
5 kHz	1n5	20k

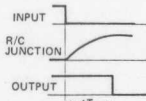
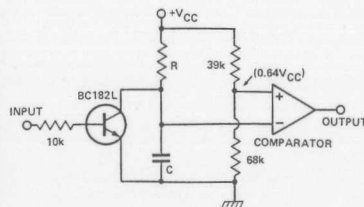
(5% tolerance)

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Comparators

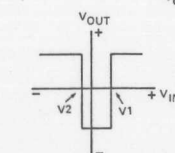
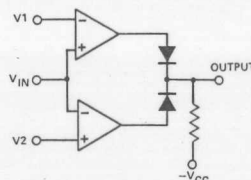


Response of a simple comparator



Time delay generator; $\Delta T = RC$

Window comparator
V1 and V2 can be defined by resistors
or can be set by any voltage
Note that V1 must be more positive
than V2

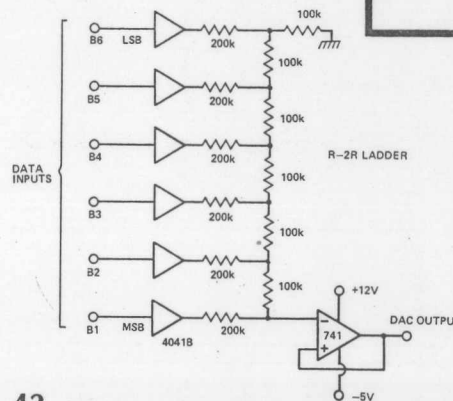
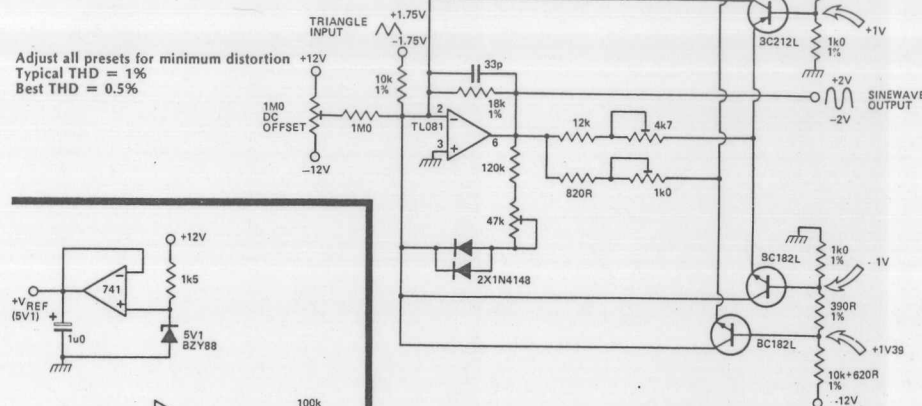


Standard comparators
LM311 single
LM339 quad
LM361 very fast single
LM3914 linear 10-section
LM3915 log 10-section

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Triangle To Sine Wave Converter

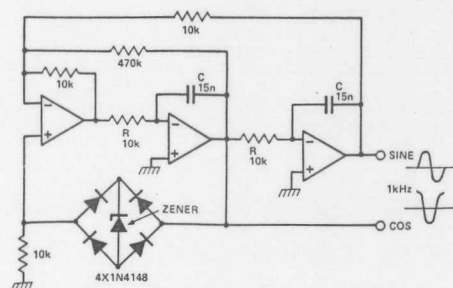
Adjust all presets for minimum distortion
Typical THD = 1%
Best THD = 0.5%



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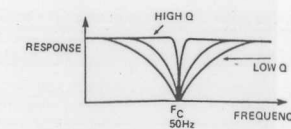
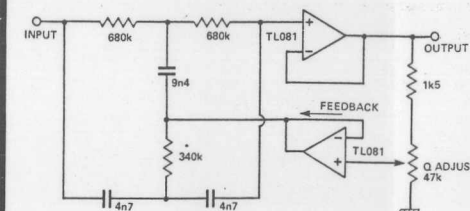
Six-bit DAC — 10-bit Precision

Buffers powered from 0 V and $+V_{REF}$
Resistors in ladder need 0.1% tolerance
DAC output has 64 steps



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50 Hz Notch, Variable Q



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Dual Integrator Oscillator

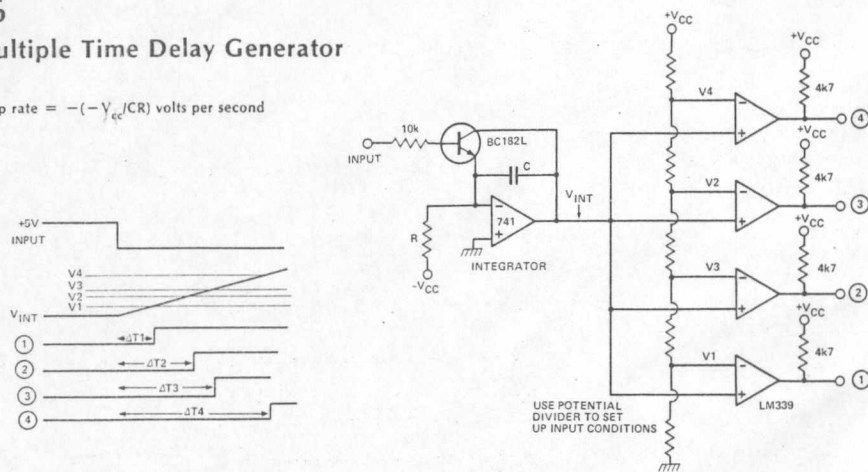
Quadrature outputs (ie sine and cosine)

$$\text{Output frequency } F = \frac{1}{2\pi RC} \text{ Hz}$$

To change frequency, change both R's or both C's.
Maximum frequency ~ 20 kHz
Minimum frequency ~ 0.016 Hz using $C = 1\mu\text{F}$, $R = 10\text{M}$, and TL081
op-amps
Oscillation amplitude = $2 \times (\text{zener voltage} + 1V_2) V_{pp}$

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Multiple Time Delay Generator

Ramp rate = $-(V_{cc}/CR)$ volts per second

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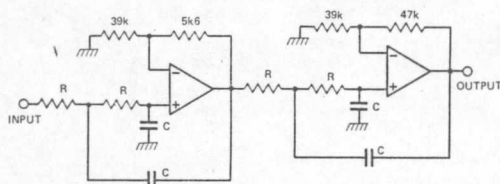
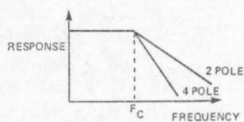
Low Pass Active Filters

Inputs must have a DC path to ground

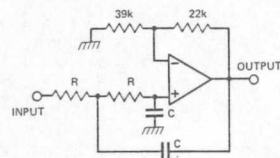
$$F_c = \frac{1}{2\pi RC}$$

2 pole roll-off = -12 dB/octave
4 pole roll-off = -24 dB/octave

R	C	F _c
107k	15n	100 Hz
10k7	15n	1 kHz
10k7	1n5	10 kHz



4 pole Butterworth

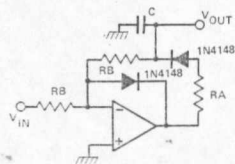


2 pole Butterworth

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Inverting Peak Voltage Detector

Attack time constant = C.RA
Decay time constant = C.RB



This circuit works well at high frequencies

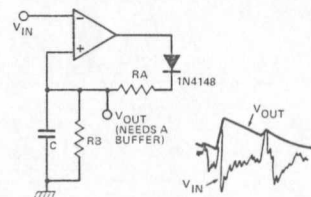
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Non-inverting Peak Voltage Detector

Input must have a DC path to ground

Keep RA greater than 1k0 to avoid
dumping large currents to ground
via C

Attack time constant = C.RA
Decay time constant = C.RB



This circuit is not suited for high frequency
operation

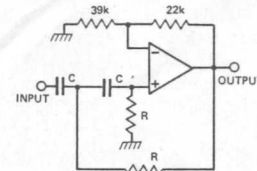
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High Pass Active Filters

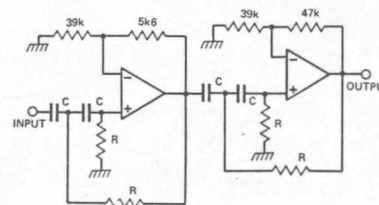
$$F_c = \frac{1}{2\pi RC} \text{ Hz}$$

2 pole roll-off = +12 dB/octave
4 pole roll-off = +24 dB/octave

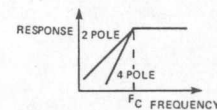
R	C	F _c
107k	15n	100 Hz
10k7	15n	1 kHz
10k7	1n5	10 kHz



2 pole Butterworth



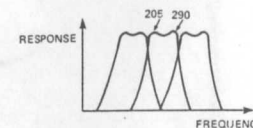
4 pole Butterworth



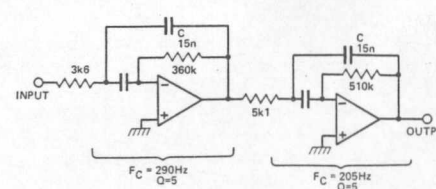
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Double Tuned Band Pass

Filter section has been designed for one octave
spacing. To alter the components for the other
octaves, scale the resistors or the capacitors,
ie changing C to 7n5 increases the filter
frequency by one octave.

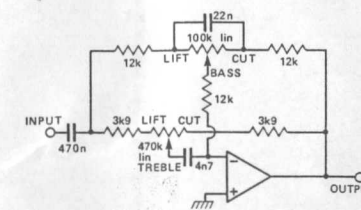


Typical filter bank response

F_c = 290Hz
Q=5F_c = 205Hz
Q=5

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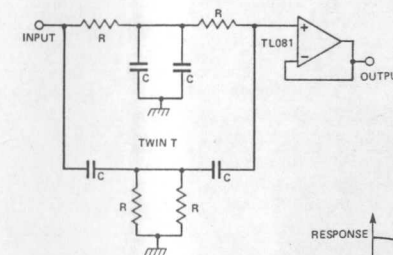
Bass and Treble Control



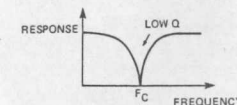
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Active Notch Filter

The two R's in parallel represent R/2
The two C's in parallel represent 2C
For 50 Hz, R = 680k, C = 4n7 (a hum remover)



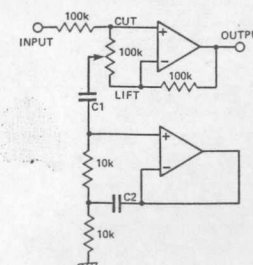
$$F_c = \frac{1}{2\pi RC}$$



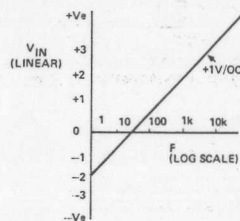
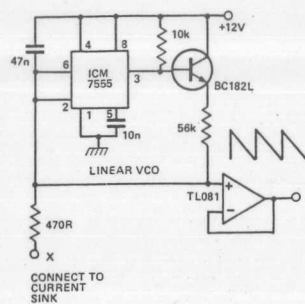
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Middle Tone Control

Input must have a DC path to ground



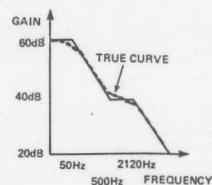
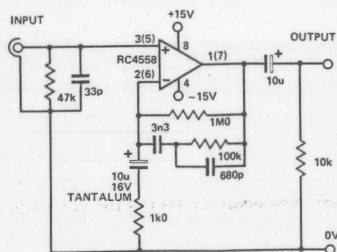
64 Exponential Current Sink



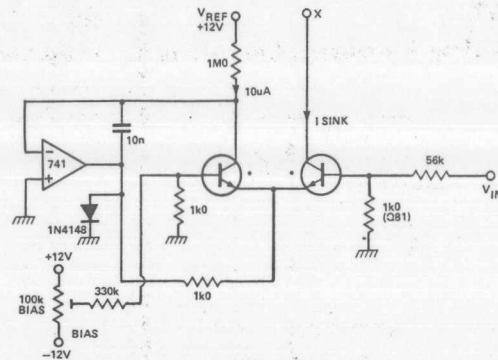
Frequency response of a linear VCO driven by an exponential current sink

65 RIAA Preamp

Suitable for use with magnetic cartridge
Use RC4558 for low noise

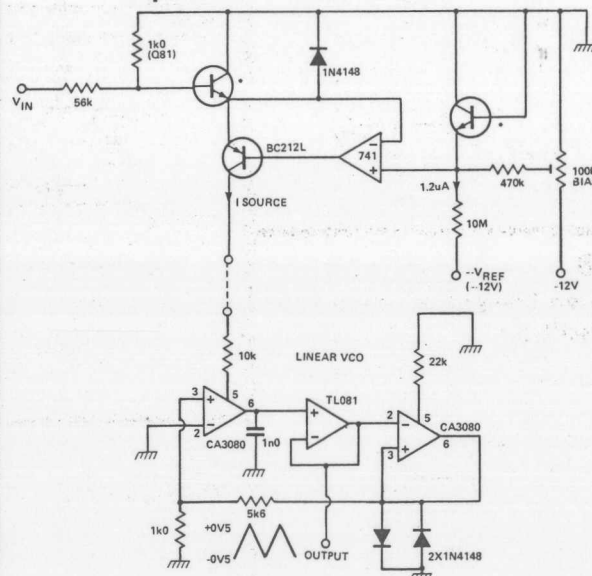


RIAA playback curve



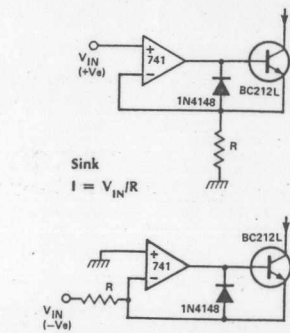
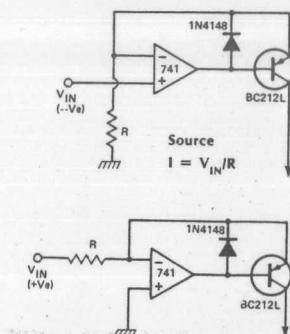
*Matched transistors in thermal contact

66 Exponential Current Source



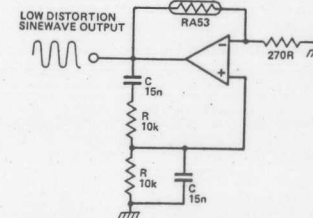
An exponential current source can be used to drive a linear VCO.
The VCO then has a 1 V/octave response
Devices all powered from ± 12 V
*Matched transistors in thermal contact

67 Voltage-to-current Converters



68 Wien Bridge Sine Wave Oscillator

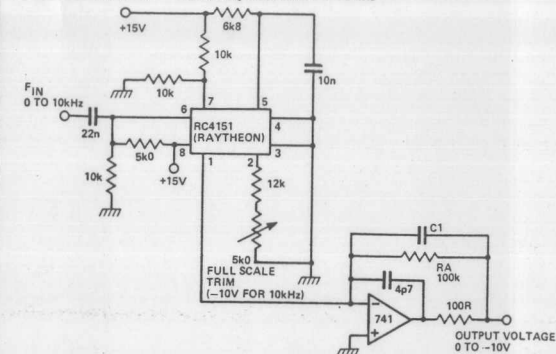
$$\text{Output frequency } F = \frac{1}{2\pi RC} \text{ Hz}$$



The RA53 is a negative temperature coefficient thermistor; it sets A_v to 3 for stable oscillation.

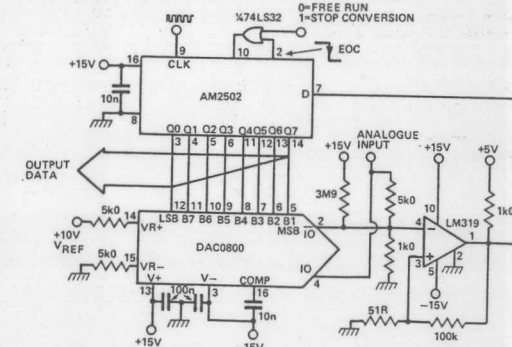
69 Frequency-to-voltage Converter

With $C1 = 100n$, ripple is 100 mV
Response time = $RA \cdot C1$
If $RA = 100k$, $C1 = 100n$, response time = 10 ms

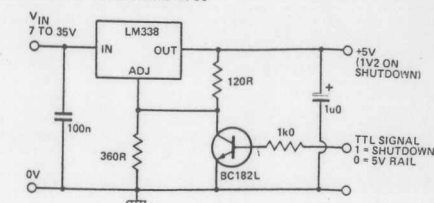


70 Eight-bit ADC

This circuit uses an eight-bit DAC plus a successive approximation register.
Conversion time 9 clock periods

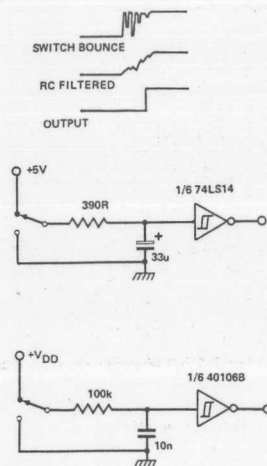


71 Electronic Shutdown



55

Switch Debouncing Using Schmitt Triggers

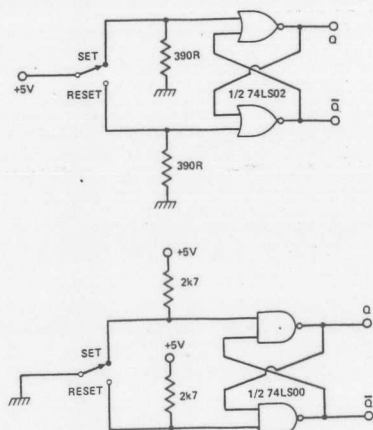


56

Switch Debouncing Using Flip-flops

Flip-flop using NOR gates Flip-flop using NAND gates

S	R	Q	$\bar{Q}$	S	R	Q	$\bar{Q}$
1	0	0	1	0	1	1	0
0	1	1	1	1	0	0	1

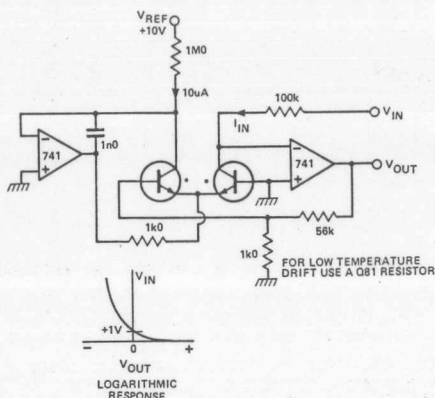


57

Log Converter

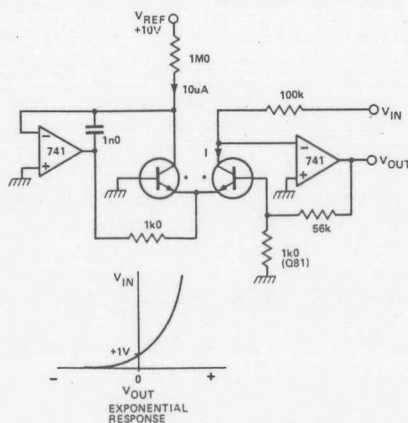
 V_{OUT} changes by 1 V for every octave change of the I_{IN} current

*The matched transistors can be two BC212L in thermal contact, or a dual transistor (LM394), or part of an array (CA3046)



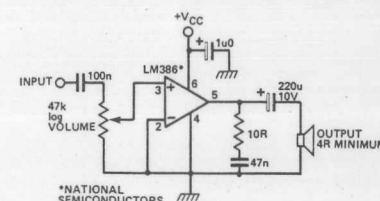
58

Antilog (Exponential) Converter

 $V_{OUT} = I \times 100k$
The current I doubles for every 1 V increase of V_{IN}
When $V_{IN} = 0$ V, $I = 10 \mu A$ 

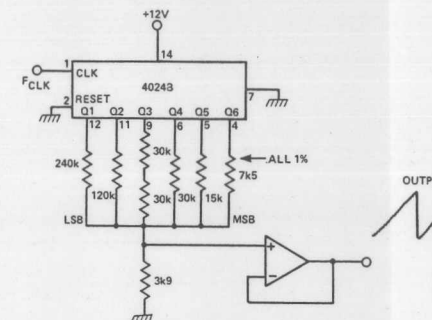
59

Low Voltage Power Amp

Voltage gain (fixed) = $\times 20$ (26 dB)
 $+V_{CC}$ range = +4 V to +12 V
Typical quiescent current = 4 mA (suitable to PP3 use)
Output power = 0W7 (if $+V_{CC} = 9$ V, speaker = 8R)
THD = 10%

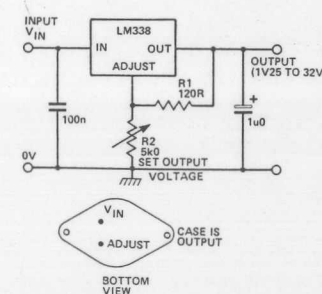
61

Staircase Generator

Output frequency $F = F_{CLK}/64$
Staircase is made up of 64 steps

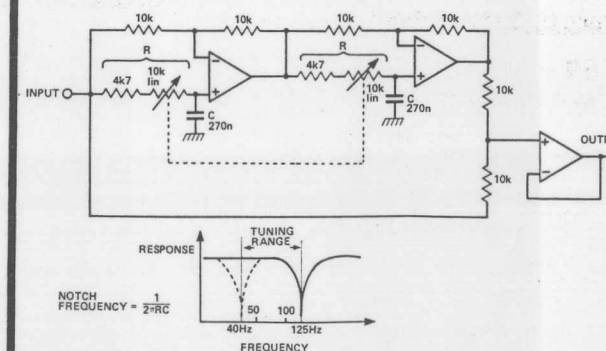
60

5 A Regulator

LM338 parameters:
Maximum input/output difference = 35 V
Maximum output current = 5 A
Ripple rejection = 85 dB
Thermal resistance, junction to case = $1^\circ C/W$ $V_{OUT} = 1.25 (R1 + R2)/R1$
 $P_{DISS} = I_{OUT}(V_{IN} - V_{OUT})$. Use a heatsink.

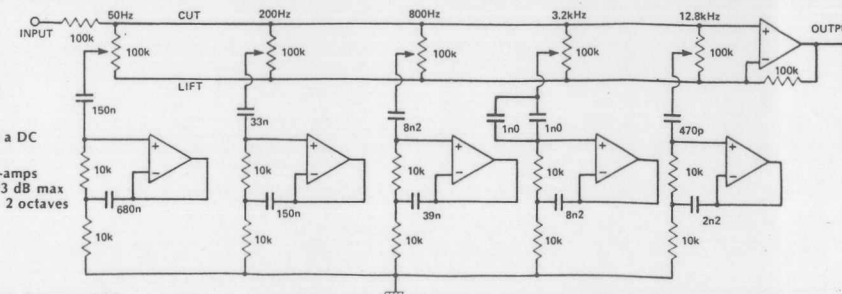
62

Notch Filter (Hum Remover)

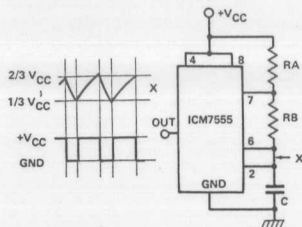
Notch frequency = $1/2 \pi RC$ 

63

Graphic Equaliser

Input must have a DC path to ground
Use 741's for op-amps
Cut and lift = 13 dB max
Filter spacing = 2 octaves

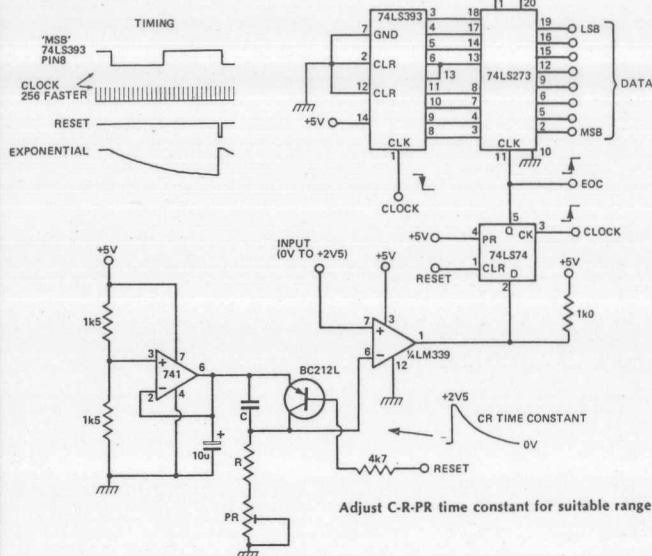
87 CMOS 555 Oscillator



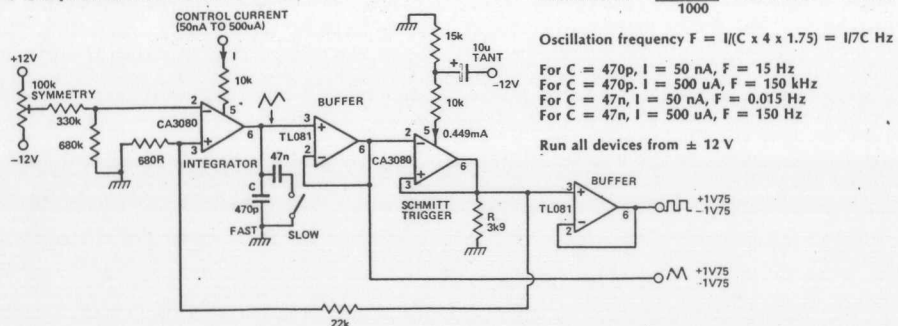
Output frequency $F = 1.46/C(RA + RB)$
 C in farads, R in ohms
 Quiescent current $\sim 120 \mu A$
 Input current $\sim 50 pA$ (this allows the use of resistors up to 10M in value)
 Frequency range 0.001 Hz to 500 kHz
 Supply range 2 to 18 V
 Rise and fall time (pin 3) = 40 ns

RA, RB	C	F
10M	10u TANT	7.3 mHz
1M0	1u0	0.73 Hz
100k	100n	73 Hz
10k	10n	7.3 kHz
10k	1n0	73 kHz

88 Logarithmic ADC



89 Linear VCO/Function Generator



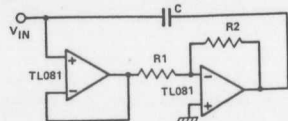
$$\text{Schmitt levels} = \frac{R \times 0.449}{1000} = 3.9 \times 0.449 = \pm 1V75$$

$$\text{Oscillation frequency } F = I/(C \times 4 \times 1.75) = I/7C \text{ Hz}$$

For $C = 470p$, $I = 50 nA$, $F = 15 \text{ Hz}$
 For $C = 470p$, $I = 500 \mu A$, $F = 150 \text{ kHz}$
 For $C = 47n$, $I = 50 nA$, $F = 0.015 \text{ Hz}$
 For $C = 47n$, $I = 500 \mu A$, $F = 150 \text{ Hz}$

Run all devices from $\pm 12 \text{ V}$

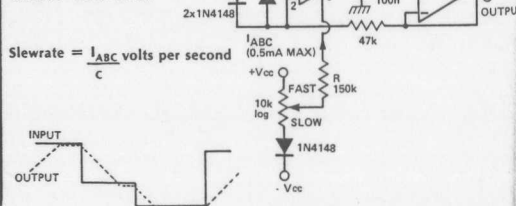
90 Capacitance Multiplier



The input looks like a capacitor C_{IN} where $C_{IN} = C(R1 + R2)/R1$

Circuit can be used to synthesise large capacitors (NB equivalent in impedance, not energy storage)

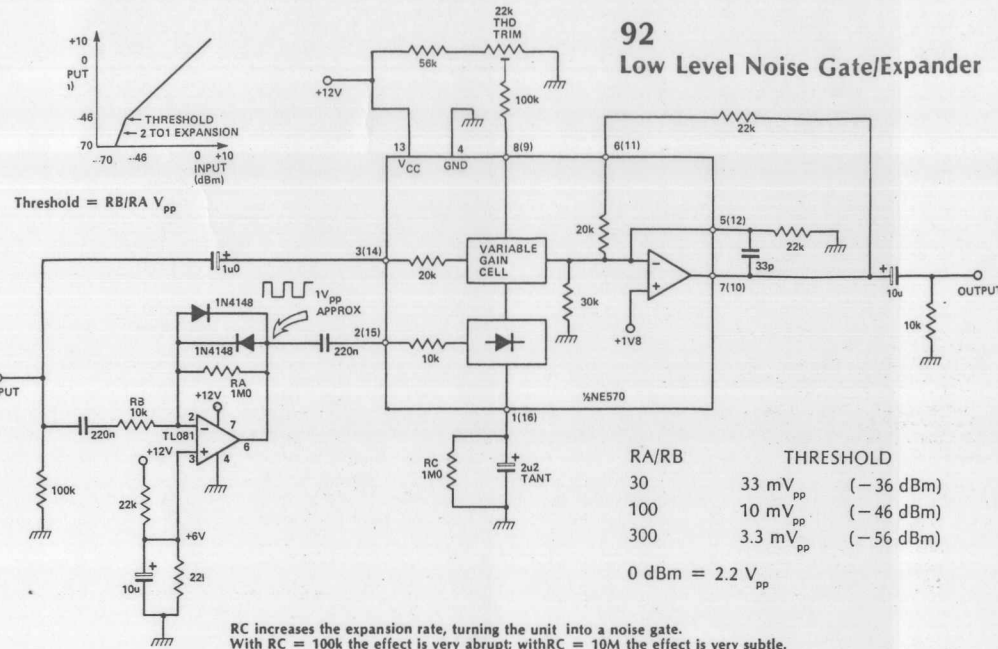
91 Slew Limiter



$$\text{Slewrate} = \frac{I_{ABC} \text{ volts per second}}{C}$$



Electronics Digest, Summer 1983

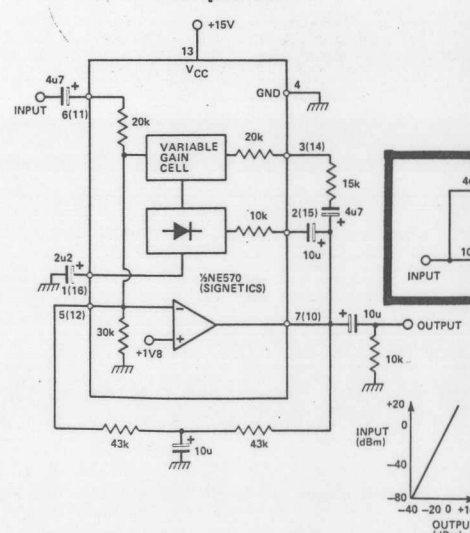


RA/RB	THRESHOLD
30	33 mV _{pp} (-36 dBm)
100	10 mV _{pp} (-46 dBm)
300	3.3 mV _{pp} (-56 dBm)

0 dBm = 2.2 V_{pp}

RC increases the expansion rate, turning the unit into a noise gate.
 With RC = 100k the effect is very abrupt; with RC = 10M the effect is very subtle.

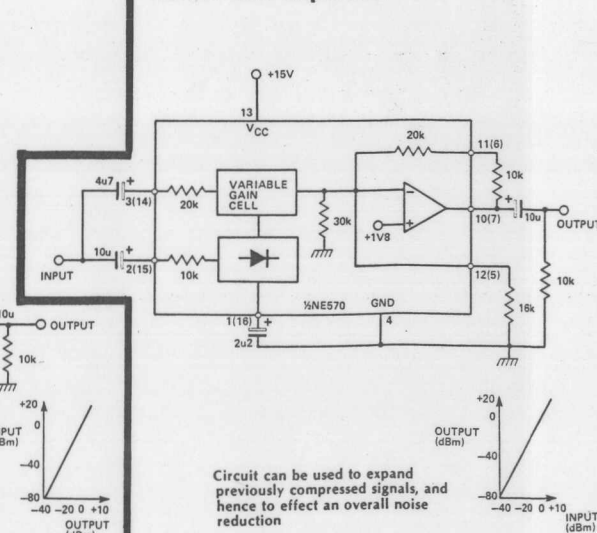
93 Two-to-one Compressor



The pin numbers in brackets refer to the second circuit in the IC.
 Circuit can be used as a preconditioner in a noise reduction system.

Electronics Digest, Summer 1983

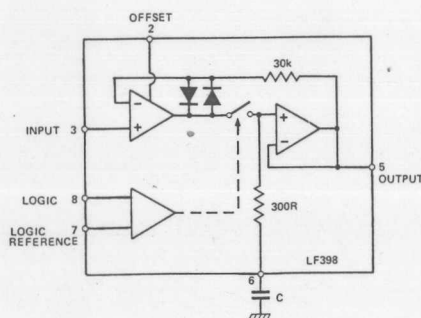
94 Two-to-one Expander



Circuit can be used to expand previously compressed signals, and hence to effect an overall noise reduction

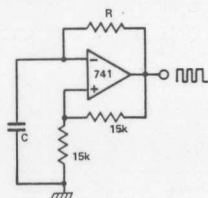
95 Monolithic Sample And Hold

Logic high = sample
Logic low = hold
Logic reference = TTL or CMOS



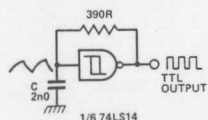
Use a printed circuit guard ring (connected to the output voltage) around the hold capacitor

96 Op-amp Oscillator



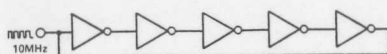
$$F \sim \frac{1}{RC} \text{ (rule of thumb)}$$

97 TTL Oscillator



Vary C to change frequency
Do not increase the size of the 390R resistor
Frequency range = 1 Hz to 1 MHz

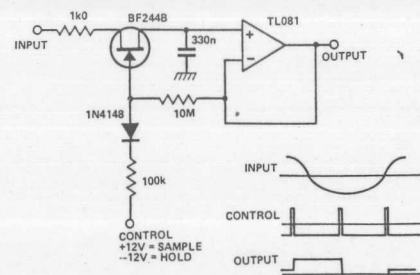
98 TTL Ring Oscillator



$F = 1/(5 \times \text{propagation delay})$
For TTL inverters (74LS04) total propagation delay = 20 ns

99 FET Sample And Hold

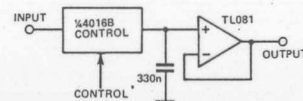
Control = +12 V; sample
Control = -12 V; hold



Use a printed circuit guard ring (connected to the output voltage) around the hold capacitor

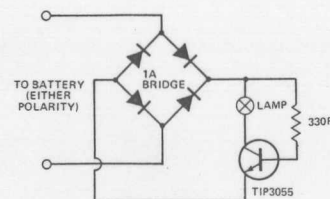
100 4016 Sample And Hold

Control = $+V_{CC}$; sample
Control = $-V_{CC}$; hold
 $-V_{CC} < \text{signal voltage} < +V_{CC}$
 $+V_{CC} - (-V_{CC}) \leq 15 \text{ V}$



Use a printed circuit guard ring (connected to the output voltage) around the hold capacitor

101 Battery Eliminator



A free bonus!
Lamp glows to show circuit is in operation
Lamp goes out when battery has been eliminated
Patent applied for

Making PCBs

One of the neatest ways of building up a circuit is on printed circuit board. In this special feature, guest writer Don Keighley shows what a printed circuit board is and how to make your own

PRINTED CIRCUIT BOARDS — PCBs — are used extensively because they provide a neat and reliable way of holding components and of making the necessary connections between them. In the days before PCBs, circuits were built up underneath a large metal chassis with the components strung between connection points — tag strips, they were called — in a seemingly haphazard manner. You only have to look inside an old valve radio or TV to get the point. All electronics manufacturers must have breathed a sigh of relief when PCBs were invented.

PCBs aren't used only in industrial equipment — they are equally suitable for the hobbyist. The difference between commercial/industrial PCBs and those we make at home is really only in the techniques used.

Board Stiff

Now that you know why a PCB is used, let's backtrack a little and see just exactly what it is. Any PCB starts life as copper-clad board — a thin base-board (about 2 mm) of insulating material (such as fibre-glass or resin-bonded paper) with an even thinner (about 0.25 mm) copper coating on one side. Figure 1 shows a cross-section of a piece of copper-clad board. Some highly specialised circuits may be built on boards with copper on both sides — called, naturally, double-sided PCBs.

To turn this copper-clad board into a PCB we have to remove all excess areas of copper, leaving behind only those areas (which make up the foil pattern) that we want. After this it's a simple job to drill the holes and to insert and solder components in their places.

By this time you'll be wondering, no doubt, how you 'remove' the areas of copper which aren't wanted — do you need a laser gun to blast them off the face of the earth? Or perhaps Superman might fly along to save the situation and burn them away with his infra-red vision?

The answer is nothing quite as sci-fi as that I'm afraid; in fact it's all down to pure, old-fashioned school chemistry. You see, copper is a metal and metals are dissolved by acids. So all we have to do is place the board into acid and the areas of unwanted copper will be rapidly dissolved (etched) away. But now we have another problem — surely the acid will etch away the wanted areas as well? Well, it will if we let it. But, if we cover up the wanted copper, in the shape of the required foil pattern (as shown in Fig. 2), with acid-resisting material before putting the board into the acid, then those areas will remain unetched when the rest has disappeared (see Fig. 3).

Down To The Nitty-Gritty

By now, you'll have realised that the production of any PCB goes through three stages:

- design of the PCB foil pattern to suit the circuit
- application of resist in the shape of that foil pattern
- etching of the PCB until unwanted copper areas are removed, subsequent removal of etch-resist and drilling of the component holes prior to circuit make-up.

Unless the board is too complicated and large for a hobbyist to tackle (or is the subject of copyright), most electronics magazine publish details of the PCBs used for their projects. Figure 4 and 5 show how these are usually published, as an overlay and a foil pattern, so that you can make your own PCB if you want (magazine usually also have some sort of service so that you can buy ready-made PCBs).

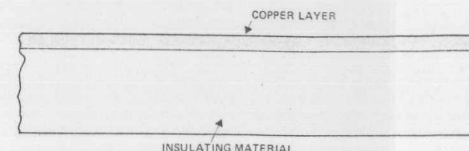


Figure 1. Cross-section of a piece of copper-clad board.

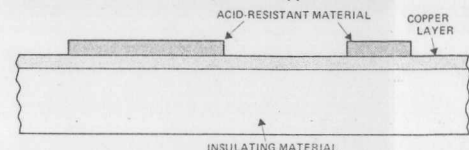


Figure 2. Cross-section of copper-clad board with acid-resistant material applied in the shape of the foil pattern.

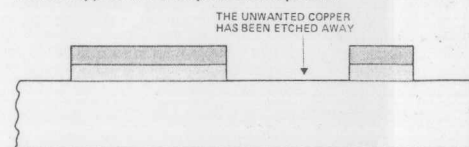


Figure 3. After etching, the unwanted copper is etched away and those areas in the shape of the foil pattern (with acid-resisting material) remain.

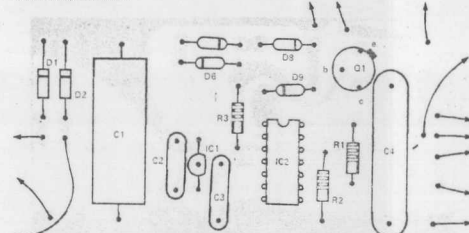


Figure 4. The printed circuit board of the Intelligent NeCad Charger in the January 1982 issue of Hobby Electronics.

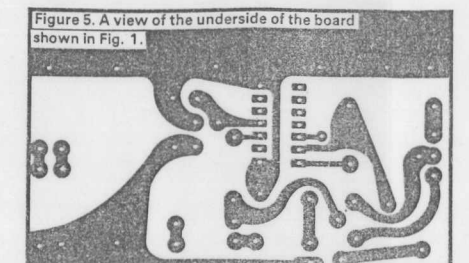


Figure 5. A view of the underside of the board shown in Fig. 1.